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Four new species in the lichen genus *Diorygma*

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Abstract—Four new species of the genus *Diorygma*, with norstictic and salazinic acid as major compounds, namely *D. dealbatum, D. inaequale, D. manipurense* and *D. verrucirimosum* have been described from India. The occurrence of only norstictic and salazinic acid in combination is very rare in *Diorygma* and so far only one species of *Diorygma* containing norstictic and salazinic acids has been reported.

Keywords—lichenized fungi, ascomycetes, taxonomy, *Graphidaceae*

Introduction

In our recent survey of the lichen family *Graphidaceae* from India we have recorded the occurrence of several species in this family with hyaline, transseptate ascospores (Adawadkar & Makhija 2004, 2006, 2007; Makhija & Adawadkar 2003, 2005a, b, 2007; Makhija et al. 2005, 2007). Currently we are undertaking studies on taxa with muriform ascospores in this family and we have found several species that can be placed in the lichen genus *Diorygma.*

Diorygma Eschw., a widely distributed, tropical to subtropical lichen genus with twenty-four species at the world level, was resurrected by Staiger (2002) and monographed by Kalb et al. (2004). Subsequently, five additional species have been described, viz. *D. nothofagi* (A.W. Archer) A.W. Archer, *D. wallamanense* A.W. Archer & Elix and *D. wilsonianum* (Müll. Arg.) A.W. Archer from Australia (Archer 2006, Archer & Elix 2008), *D. taliense* (A.W. Archer) A.W. Archer from the Solomon Islands (Archer 2007), and *D. alagoense* Cáceres & Lücking from Brazil (Cáceres 2007).

The genus *Diorygma* in India is so far known from five species (Kalb et al. 2004)—*D. hieroglyphicum* (Pers.) Staiger & Kalb, *D. junghuhnii* (Mont. & Bosch) Kalb et al., *D. megasporum* Kalb et al., *D. pruinosum* (Eschw.) Kalb et al. and *D. tuberculosum* (Stirt.) Kalb et al.

The lichen genus *Diorygma* is characterized by an inconspicuous pseudocortex, which results in a matte, often granular, farinose upper surface;

lirellate ascocarps with a heavily pruinose disc; branched, anastomosing paraphyses with a thick gelatinous wall (usually only the lumina are distinctly visible); paraphysis tips which are reticulately interwoven to form an epithecium; asci of the *Graphis*-type; ascospores hyaline, very rarely brownish, transversely septate with lenticular spore locules or muriform, and the presence of norstictic, stictic and/or protocetraric acid chemosyndromes (Kalb et al. 2004).

The occurrence of norstictic and salazinic acids in combination has been reported to be very rare in *Diorygma* and *D. salvadoriense* Kalb et al. is the only previously known species having norstictic and salazinic acids (Kalb et al. 2004).

During our investigations on *Diorygma* from India we have encountered four new species with hyaline, muriform ascospores and norstictic and salazinic acids as major compounds; these are described below.

Materials & methods

Chemical data was obtained by the standard method of TLC (Culberson & Kristinsson 1970, White & James 1985) using solvent systems benzene-dioxane-acetic acid (180:45:5), hexane-ethyl ether-formic acid (130:80:20) and toluene-ethyl acetate-formic acid (139:83:8). The specimens have been deposited in the Ajrekar Mycological Herbarium (AMH).

Key to the Indian species of *Diorygma* with norstictic and salazinic acids

1a. Exciple striate, ascospores 2–4/ascus
Thallus brownish white, rough; ascocarps 0.2–0.3 mm long mostly simple to rarely branched; disc brown, 0.4–0.5 mm broad; exciple 2–5 striate, apically dark brown; ascospores muriform, 76–92 × 21–25 µm..... ***D. manipurense***

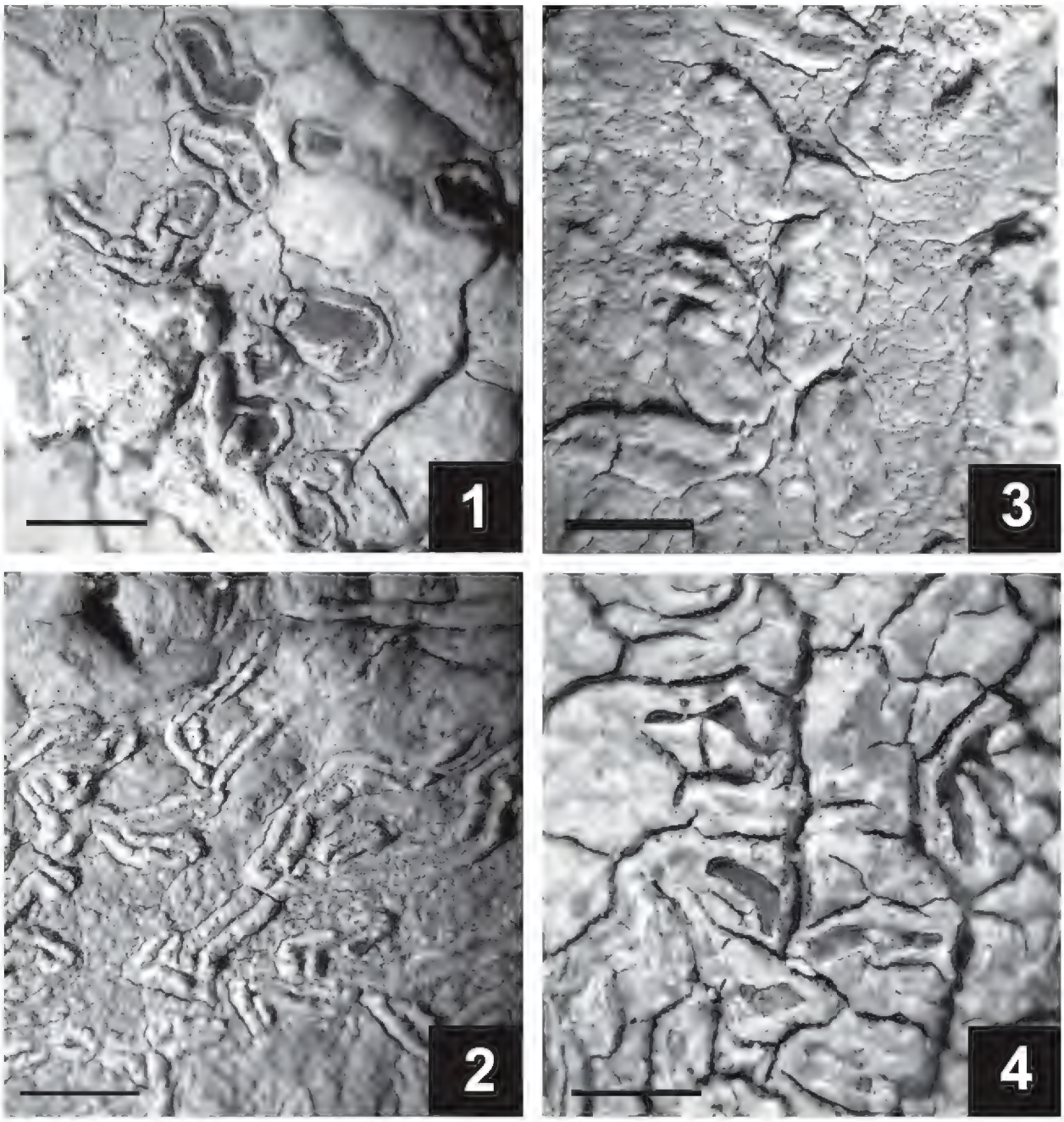
1b. Exciple not striate, ascospores 1/ascus 2

2a. Ascospores less than 100 µm long.
Thallus glaucous green, uneven, partly with tubercules; ascocarps 1–6 mm long, simple to irregularly branched; disc brown, 0.2–0.3 mm broad; exciple non-striate; ascospores muriform, 79–96 × 29–33 µm ..... ***D. inaequale***

2b. Ascospores exceeding 100 µm long 3

3a. Thallus deeply cracked and strongly verrucose.
Ascocarps crowded, short, 1–2 mm long; disc narrow to broad, sunken, reddish brown, 0.2–0.4 mm broad; exciple non-striate; ascospores muriform, 97–126 × 25–33 µm ..... ***D. verrucirimosum***

3b. Thallus not verrucose.
Thallus white with brown tinge, smooth; ascocarps close to each other, simple to branched, 0.5–2.5 mm long; disc brown to blackish brown, 0.2–0.7 mm broad; exciple non-striate; ascospores muriform, 105–147×33–37 µm .....***D. dealbatum***



Figures 1–4. Habit (Holotypes)
Diorygma dealbatum, D. inaequale, D. manipurense, D. verrucirimosum.
Bar = 1 mm

Diorygma dealbatum B.O. Sharma & Makhija, **sp. nov.** Figure 1

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Similis Diorygma salvadoreinse, *sed ascosporis minoribus et loculis aequalis. Similis* Diorygma tibelii, *sed ascis 1-sporis, ascosporis majoribus et acida norsticticum et salazinicum continens differt.*

Etymology: from the latin *dealbatus*; white upon a darker ground, a reference to thallus colous.

Holotypus—India, Tamil Nadu, Chitteri, 15.10.1985, *M.B. Nagarkar & P.G. Patwardhan, 85.1408*: AMH.

Thallus corticolous, white with brown tinge, smooth, thick, finely cracked, with a thin pseudocortex. Ascocarps rounded, lirellate, concolorous with the thallus, immersed, irregular, simple to branched, curved, 0.5–2.5 mm long, ends round, thalline margin slightly raised. Disc narrow to broad, 0.2–0.7 mm wide, brown to blackish brown, covered with a white pruina. Exciple divergent, uncarbonized, laterally poorly developed, base distinctly orange brown, broken at the base forming a canal like structure, merging into the thallus. Epithecium distinct, blackish brown. Hymenium hyaline, not inspersed, I+ blue, 125–150 µm high. Paraphyses anastomosing. Ascospores 1/ascus, hyaline, muriform, I+ blue, peripheral and central spore locules of equal size, 105–147 × 33–37 µm.

Chemistry—Norstictic and salazinic acids present.

Additional specimens examined—Tamil Nadu, Kollimalai, *M.B. Nagarkar & P.G. Patwardhan,* 85.1516, 85.1571:AMH.

Remarks—*Diorygma dealbatum* differs from *D. salvadoriense* Kalb et al. in having slightly smaller ascospores with the peripheral locules equal to the central ones. *D. salvadoriense* has large ascospores of 150–200(–230) × 50–75 µm. with the peripheral locules distinctly smaller than the central ones.

Diorygma dealbatum is somewhat similar to *Diorygma tibellii* Kalb, et al. in fine cracks, occurring especially along the lirellae, ascocarp size and morphology but differs from *D. tibellii* in having 1-spored asci and norstictic and salazinic acids. *D. tibellii* has 2–4 spored asci, smaller ascospores (55–90×(16–)20–30 µm), and stictic, peristictic, substictic, constictic and cryptostictic acids. Under *D. tibellii,* Kalb et al. (2004) reported one collection from Ecuador containing salazinic acid.

Diorygma dealbatum can easily be differentiated from *D. verrucirimosum* (vide infra) in not having a deeply cracked and verrucose thallus.

This new species was collected in northern Tamil Nadu state of India at an altitude of about 900 m where the climate is generally cooler and wetter than the surrounding plains.

Diorygma inaequale B.O. Sharma & Makhija, **sp. nov.** Figure 2

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Similis Diorygma erythrellum, *sed ascosporis majoribus et acida norsticticum et salazinicum continens differt.*

Etymology: From the latin *inaequale,* unequal, a reference to the nature of the uneven thallus.

Holotypus—India, West Bengal, 2 km to Sevak on Gauhati road, northern bank of Mahanadi, above bridge, 23.10.1977, *P.G. Patwardhan & M.B. Nagarkar, 77.641*: AMH.

Thallus corticolous, glaucous green with a yellow and or red tinge, cracked, uneven, partly with tubercules; thin pseudocortex visible, delimited by a black hypothallus. Ascocarps 1–6 mm long, ends acute to obtuse, flexuous, simple to

irregularly branched, margin distinctly raised. Disc more or less open, 0.2–0.3 mm wide, brown, covered with white pruina in young ascocarps. Exciple non-striate, divergent, non carbonized, distinctly orange at the base. Hymenium hyaline, 100–112.5 µm high, not inspersed, I+ blue. Epithecium distinctly developed, brown, consisting of brownish reticulately branched paraphysis tips. Paraphyses anastomosing. Ascospores 1/ascus, hyaline, muriform, I+ blue violet, peripheral and central spore locules of equal size, 79–96×29.4–33.6 µm.

Chemistry—Norstictic and salazinic acids present.

Remarks—The new species *Diorygma inaequale* is closely related to the South-East Asian species *D. erythrellum* (Mont. & Boasch) Kalb et al. in respect of external morphology in having an uneven thallus with small warts, and the size of the ascocarps (0.7–7 mm long). *D. erythrellum*, however, differs from *D. inaequale* in having 8 ascospores per ascus, which are smaller (30–65×12–20 µm), and a chemistry with norstictic (major), connorstictic (minor or trace) and stictic acids.

Diorygma tuberculosum, a species from Nilgiri hills of India, exhibits a similar external morphology with *D. inaequale* but differs in having slightly smaller ascospores with all spore locules of equal size and in chemistry. *D. tuberculosum* has larger ascospores (100–130×44–48 µm), with the peripheral spore locules distinctly smaller than the central ones and with norstictic and connorstictic acids but no salazinic acid.

Diorygma inaequale differs from *D. manipurense* (vide infra), a species with same ascospore size, by its entire, non striate exciple, and 1 ascospore per ascus compared to 2–4 ascospores per ascus in *D. manipurense.*

The species was collected from semi-evergreen forests at high–altitudes in Kerala, Tamil Nadu and West Bengal, where the climate is generally comparatively cooler.

Additional specimens examined—Kerala, Wayanad forest, *S.P. Kekre & P.K. Sethy*, 81.749; on the way to Valparai, *P.K. Sethy & P.G. Patwardhan,* 82.253. Tamil Nadu, Yercaud, *P.G. Patwardhan & M.B. Nagarkar,* 85.1354. West Bengal, 2 km to Sevak on Gauhati road, northern bank of Mahanadi above bridge, *P.G. Patwardhan & M.B. Nagarkar*, 77.642, 77.653-AMH

Diorygma manipurense B.O. Sharma & Makhija, **sp. nov.** Figure 3

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Similis Diorygma salvadoriense, *sed ascis 2–4 sporis, et ascosporis minoribus differt.*

Etymology: from the Latin *ensis,* a place of origin, and Manipur, the type locality.

Holotypus—India, Manipur State, Near Mao, 1 km from Mao on Imphal road in ravine, 8.11.1977, *P.G. Patwardhan & M.B. Nagarkar, 77.1510*: AMH.

Thallus corticolous, brownish white, ± smooth to rough, uneven, delimited by a distinct, thin blackish hypothallus. Ascocarps concolorous with the thallus,

lirellate, narrow, flattened, immersed, irregular, curved, more or less flexuouse, 0.2–0.3 mm long, ends obtuse, mostly simple to rarely branched, thalline margin raised. Disc narrow to distinctly open, 0.4–0.5 mm wide, brown, white pruinose. Exciple convergent to divergent, with 2–5 thin striae, apically dark brown, colourless at the base. Hymenium hyaline, 130–150 µm high, not inspersed, I+blue. Epithecium brownish, consisting of reticulately branched, hyaline or brownish paraphyses tips. Paraphyses anastomosing. Ascospores 2–4/ascus, hyaline, muriform, I+blue violet, peripheral and central spore locules of equal size, 76–92 × 21–25 µm.

Chemistry—Norstictic and salazinic acids present.

Remarks—*Diorygma manipurense* is distinguished from *D. salvadoriense*, a species also containing norstictic and salazinic acids, by its non flaking thallus, and 2–4/ascus, smaller ascospores (76–92×21–25 µm). *D. salvadoriense* has flaking thallus, and 1/ascus, much larger ascospores (150–200(–230)×50–75 µm).

Diorygma megasporum, which also has a striate exciple and is known from India, has different characters and does not contain salazinic acid.

Diorygma manipurense is so far known from the type locality Mao in the Manipur State of India and was collected at about 1788 m altitude from the evergreen forest.

Diorygma verrucirimosum B.O. Sharma & Makhija, **sp. nov.** Figure 4

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Similis Diorygma circumfusum, *sed ascosporis muriformis differt.*

Etymology: from the latin *verruca,* wart, and *rimosus*, with numerous cracks, a reference to the nature of thallus

Holotypus—India, Tamil Nadu, Yercaud, 13.10.1985, *M.B. Nagarkar & P.G. Patwardhan, 85.1368*: AMH.

Thallus corticolous, glaucous grey, deeply cracked, distinctly verrucose, margin of the thallus white, hypothallus not distinct. Ascocarps crowded, concolorous with the thallus, irregular, flexuous, curved, immersed, short, 1–2 mm long, ends acute to obtuse, thalline margin slightly raised. Disc narrow to wide, sunken, 0.2–0.4 mm wide, reddish brown covered with white pruina. Exciple covered by crystals, divergent, uncarbonized, base distinctly orange brown. Epithecium distinct, brown to hyaline. Hymenium hyaline, not inspersed, I+ blue, 123–150 µm high. Paraphyses anastomosing. Ascospores 1/ascus, hyaline, muriform, I+ blue, peripheral and central spore locules of equal size, 97–126×25–33 µm.

Chemistry—Norstictic and salazinic acids present.

Additional specimens examined—Tamil Nadu, Yercaud, *M.B. Nagarkar & P.G. Patwardhan,* 85.1369, 85.1388, 85.1824-AMH

Remarks—*Diorygma verrucirimosum* differs from the other species of *Diorygma* described in the present paper by its deeply cracked and verrucose thallus. *Diorygma circumfusum* (Stirt.) Kalb et al. also has thallus with many fine or deeper cracks, especially along the lirellae similar to *D. verrucirimosum* but *D. circumfusum* differs from the new species in having transversely septate ascospores and a different chemistry.

The species was collected from Yercaud situated in the Shevaroy Hills of Tamil Nadu State of India at an altitude of about 1500 m from the semievergreen forest.

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